Vertebral Artery Position in the Setting of Cervical Degenerative Disease: Implications for Selective Cervical Transforaminal Epidural Injections

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Summary

Cervical transforaminal epidural injections (C-TfEI) are commonly performed in patients with cervical radiculopathy/pain. C-TfEIs are typically performed without incident but adverse events can occur. Using CT-fluoroscopy-guided C-TfEI, we commonly observe the vertebral artery in proximity to the target injection site. The purpose of this study was to assess the position of the vertebral artery relative to the typical C-TfEI injection point.

CT-fluoroscopy-guided C-TfEIs were performed at 70 levels in 68 patients with radiculopathy/neck pain (age range 19-83 yrs, mean 50.6 yrs). Degenerative neural foraminal narrowing at each level was characterized (normal-to-mild, moderate, severe). Vertebral artery position was categorized as: anterior (normal), partially covering neural foramen, complete/near-complete covering the neural foramen. Additional measured variables included angle of needle trajectory, foraminal angle, and whether or not needle trajectory intersected with the vertebral artery.

Foraminal vertebral artery covering correlated with severity of foraminal degenerative narrowing (p=0.003). Complete/near-complete covering was seen in: 65% severely narrowed foramina, 30% moderately narrowed foramina and 10% normal/mildly-narrowed foramina. Needle trajectory intersected with the vertebral artery in 30 of 70 injections (46%) by CT-fluoroscopy, frequently associated with shallow (lateral) approaches. Foraminal angle, approximating oblique fluoroscopic technique, suggests needle trajectory intersection with the vertebral artery in 27 of 70 foramina (39%).

Vertebral artery position is commonly displaced into the foramen in patients with advanced cervical degenerative disease. Operator awareness of altered vertebral artery position is important for determination of optimal needle trajectory and tip placement prior to injection in patients undergoing C-TfEI.

Introduction

Selective cervical transforaminal epidural injection (C-TfEI; nerve root block and/or steroid administration) is a common image-guided interventional spine procedure used for diagnosis and treatment of radiculopathy/neck pain secondary to cervical nerve root compression. Various C-TfEI percutaneous techniques have been described including the use of CT, CT-fluoroscopy or conventional fluoroscopic guidance[1-6]. Although several large series examining the safety of C-TfEI have demonstrated a low rate of serious complications[3,7,8,] adverse events can occur due to proximity of vascular structures such as the vertebral artery and radiculomedullary arteries to the target injection site[8-12].

In our practice using CT-fluoroscopy to perform C-TfEI, we observed that degenerative changes often appear to alter the position of the vertebral artery with respect to the target injection site thus potentially increasing the risk of inadvertent interaction with the vessel during needle placement/injection. The aims of this study were 1) to evaluate the vertebral artery position relative to the size (degenerative characteristics) of the cervical neural foramen and 2) to assess the typical needle trajectory relative to the position of the vertebral artery, in a consecutive series of patients undergoing CT-fluoroscopy-guided cervical transforaminal epidural injection (C-TfEI).

Methods

Over a one-year period 70 consecutive C-TfEIs were performed were performed in 68 patients on the service of one interventional spine neuroradiologist for cervical radiculopathy and/or neck pain (33 male; 35 female; average age: 50.6 yrs [range: 19-83 yrs]). Patients were typically referred by spine-focused neurosurgeons after failure of conservative management including oral steroids and physical therapy. Injection locations included: C4 nerve root: 6 injections, C5 nerve root: 21 injections, C6 nerve root: 21 injections and C7 nerve root: 22 injections. Procedure imaging of these 68 patients was retrospectively reviewed and analyzed. Institutional review board approval was obtained for this retrospective study.

C-TfEI Technique

C-TfEIs were performed in all cases using CT-fluoroscopic guidance with patients in the supine position. Patient evaluation prior to the procedure included confirmation of the indication for the treatment and assessment of the pre-procedure cervical spine imaging (typically pre-procedure MR imaging). Initial non-enhanced CT images (2.5 mm collimation; 120 kVp; 220 mA) were acquired through the level of interest including a reference location for accurate counting (C2 or C7-T1) to plan the most appropriate approach and trajectory to the targeted nerve root. Approach trajectory (lateral, anterolateral, or posterolateral) was chosen so as to avoid intersecting the patient's jugular vein and/or carotid artery.

After the neck was cleansed, a 25-guage spinal needle was introduced into the skin entry point as defined by pre-procedure trajectory planning and gradually advanced using intermittent CT-fluoroscopy guidance (2.5 mm collimation; typically 120-140 kVp and 30-50 mA depending on patient body habitus) employing a soft tissue algorithm. The needle tip was directed to or into the posterior aspect of the foraminal zone, ideally immediately anterior to the superior articular process of the subjacent cervical vertebrae. Final needle tip position was dependent upon approach trajectory (lateral, anterolateral, posterolateral) and vertebral artery position. For the anterolateral approach, the needle tip was placed slightly into the posterior foramen if the vertebral artery was located anteriorly, or at the posterior bony margin of the foramen if the vertebral artery covered the foramen. For lateral and posterolateral approaches, the needle tip was placed along the posterior bony margin of the foramen as far into the foramen as possible so as not to interact with the vertebral artery. Extravascular location of the needle tip was confirmed with a small volume injection of non-ionic contrast material (0.3 cc Iohexol 180 mgI/cc) with CT-fluoroscopic confirmation of extravascular contrast accumulation adjacent to the exiting nerve root. If distinct contrast accumulation was not identified, the needle position was adjusted until focal accumulation and an internal wheal could be established. Therapeutic injections consisted of 8 mg of decadron (0.8 cc) co-mixed with 1 cc bupivacaine 0.25%.

Image Analysis

Vertebral artery position was judged relative to the size of the vertebral foramen. Foramen size and vertebral artery position were assessed in the axial image used for trajectory planning. CT-fluoroscopy needle trajectory angle was measured on an intra-procedural CT-fluoroscopy image obtained at final needle placement. Data were collected by consensus review by two neuroradiologists.

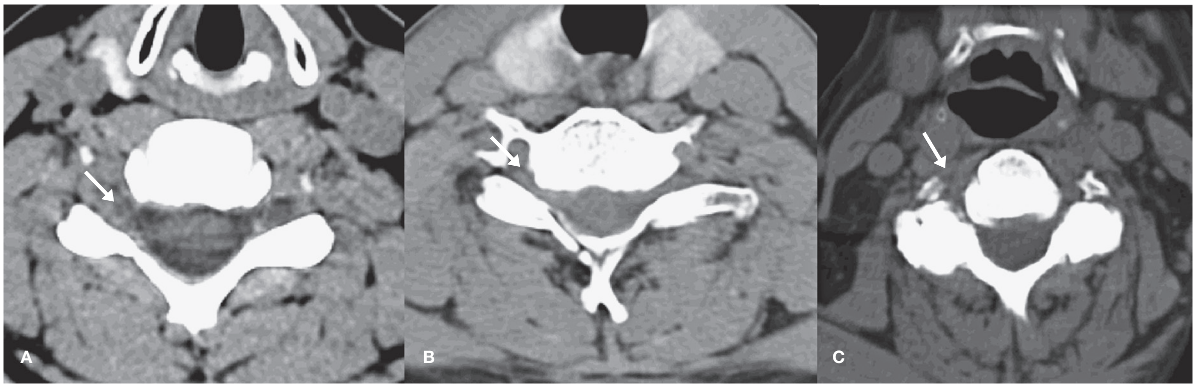

Figure 1 Axial non-enhanced CT images in three patients demonstrating examples of neural foraminal grading. A) Normal to mild degenerative narrowing. B) Moderate degenerative narrowing. C) Severe degenerative narrowing.

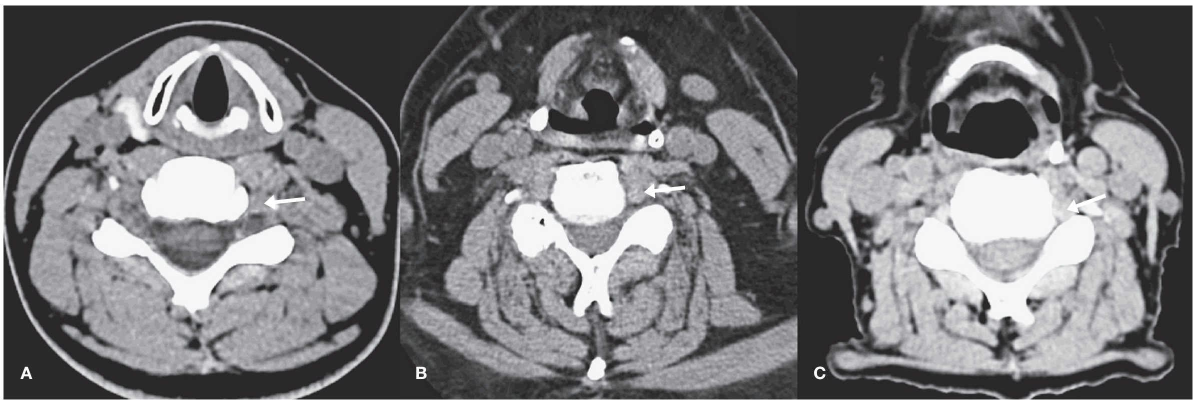

Figure 2 Axial non-enhanced CT images in three patients prior to CNRB illustrating vertebral artery position. A) Normal vertebral position. B) Partial coverage of the lateral aperture of the foramen. C) Complete/near-complete coverage of the foramen.

Neural foraminal size was judged as: 1) normal-to-mild degenerative narrowing (up to 1/3 reduction in diameter), 2) moderate degenerative narrowing (1/3-2/3 reduction in diameter) or 3) severe degenerative narrowing (>2/3 reduction in diameter) as judged visually in the axial plane (Figure 1 A-C).

Vertebral artery position was classified as: 1) normal (vertebral artery lies anterior or minimally into the lateral aperture of the neural foramen, in line with foramen transversarium), 2) partially covering the lateral aperture of the neural foramen, or 3) completely/near-complete covering the lateral aperture of the neural foramen (Figure 2 A-C).

The angle of needle trajectory at CT-fluoroscopy was measured relative to horizontal, with zero indicating a horizontal approach, negative angle indicating a posterolateral approach, and positive angle denoting an anterolateral approach. Needle trajectories were also judged according to whether continuation of the needle path would overlap with any portion of the vertebral artery (Figure 3).

The representative fluoroscopic approach was chosen to be parallel to the posterior wall of the target neural foramen, similar to the approach related to oblique fluoroscopy. The foraminal angle, approximating the fluoroscopic approach angle, was measured on the CT scout images parallel the posterior wall of the neural foramen and reported relative to horizontal. Vertebral artery position was tabulated relative to the foraminal angle.

Statistical Analysis

Comparison between foramen size and vertebral artery position was evaluated using the Chi squared and Kendall's tau-b assessments (SPSS version 18). Results were considered statistically significant if $p \leq 0.05$.

Figure 3 43-year-old woman with right neck pain radiating to the proximal right upper extremity referred for right C5 NRB. Axial CT image during the process of CT-fluoroscopy guided needle placement at the level of the right C4/5 neural foramen demonstrates intersection of the needle trajectory with the vertebral artery as demonstrated by streak artifact (solid arrow). Of note, the position of the carotid sheath (dashed arrow) influences the available trajectory angle such that avoidance of the sheath requires a more shallow approach.

Results

The results for vertebral artery position relative to degenerative foraminal narrowing are summarized in Table 1. Foraminal vertebral artery covering correlated with severity of foraminal degenerative narrowing. Complete/near-complete neural foramen covering was identified in 15 of 23 (65%) severely narrowed foramina and 11 of 37 (30%) moderately narrowed foramina. Partial neural foraminal covering was most commonly present in 17 of 37 (46%) moderately narrowed foramina. Normal vertebral artery anatomic position was typically seen with normal to moderately narrowed foramina. The relationship between vertebral artery position and foramen size was statistically significant ($\chi 2$ (1, N = 70) = 18.45, p = .001, Kendall's tau-b = .27, p = .003).

The mean needle trajectory angle for CT-fluoroscopy guided C-TfEI was 17.5° ± 15.8° (minimum: –18°; maximum: 53°). The choice of trajectory angle was primarily governed by the location of the carotid artery and jugular vein. In 30 of 70 foraminal injections (43%) intersection of the needle trajectory with the vertebral artery was seen (Figure 3; mean angle of trajectory: 6.1° ± 13.3° [minimum: -18°; maximum: 32°]). In five of these 30 injections, extreme negative needle trajectory angle was required due to carotid/jugular position (range: –10° to –18°). Needle trajectory intersected with the vertebral artery in all five of these foramina in spite of the more posterior-lateral approach due to severe foraminal narrowing and vertebral artery displacement. In 40 of 70 foraminal injections (57%) the needle trajectory did not intersect with the vertebral artery (mean angle of trajectory: 30.0° ± 11.8° [minimum: 4°; maximum: 53°]).

The mean foraminal angle among all 70 foramina injected was 37.5° ± 9.9°. Divided among the categories of vertebral artery position, the mean foramina angle was similar for all three vertebral artery locations (normal vertebral artery position: 33.5° ± 9.7°; partial covering of the neural foramen: 37.0° ± 8.3°; complete covering of the neural foramen: 41.0° ± 10.5°). The vertebral artery completely covered the foramen, potentially lying in the target trajectory location for fluoroscopically-guided C-TfEI, in 27 foramina (Table 1; normal-to-mild foraminal narrowing: 1; moderate foraminal narrowing: 11; severe foraminal narrowing: 15).

Table 1 **Vertebral artery position relative to neural foramen characterization**

Degree of Degenerative Neural Foraminal Narrowing	Vertebral Artery Position			Total
	Normal (Anterior)	Partial Coverage	Complete/Near-Complete Coverage	
Normal to mild	7	2	1	10
Moderate	9	17	11	37
Severe	4	4	15	23
Total	20	23	27	70

Discussion

Our study demonstrates a positive correlation between the severity of degenerative neural foraminal narrowing and the position of the vertebral artery. Osteophytes arising from the uncovertebral joint can displace the vertebral artery posteriorly and laterally toward the lateral aperture of the neural foramen. Hypertrophy of the facet joint or facet-associated osteophytes may shift the posterior osseous border of the foramen anteriorly toward the vertebral artery. In patients undergoing C-TfEI the vertebral artery therefore can lie in very close proximity to the typical target injection site. These changes may be further superimposed upon inherent variability of vertebral artery position including: origin of the vertebral artery, size of the vertebral artery, level of entry into the foramen transversarium, tortuosity, or altered position secondary to spine deformity or surgery[13-15]. Cervical nerve root symptoms may occasionally be secondary to direct compression by a tortuous vertebral artery[16,17]. Awareness of the potential for varied vertebral artery position, particularly in patients with advanced facet/uncinate arthropathy, can thus aid the operator in planning the safest needle trajectory and tip target position by CT or fluoroscopic guidance.

C-TfEI is increasingly utilized as a diagnostic/therapeutic tool in patients with cervical radiculopathy and/or neck pain with estimates of >30,000 procedures annually in the United States[18]. Although the relative safety of these procedures has been demonstrated in several large cases series[3,7,8,19], awareness of anatomical structures in the vicinity of the target injection site are important to recognize in order to minimize risks. This is in particular true of vascular interactions. The choice of target injection site and therefore approach/trajectory to the foramen varies greatly in the literature and among individual practitioners. Given the high degree of variability of vertebral artery position, no single target injection site or approach negates the possibility of interaction with the vertebral artery or radiculomedullary branches. Reliance on return of blood from the needle hub is <50% sensitive for the detection of intravascular needle placement[9]. Most operators rely on fluoroscopy, CT or intermittent CT fluoroscopy for guidance during needle placement and to provide verification of extravascular needle tip position prior to injection.

Multiple factors may influence the operator's choice of image guidance including equipment availability, time constraints, previous training or experience, and radiation exposure. In addition to visualization of the vertebral artery, CT or CT-fluoroscopy guidance allows visualization of non-osseous structures that may lie along the needle trajectory from the skin to the target injection site in addition to osseous landmarks that are critical in fluoroscopic-guided C-TfEI. Localization of the common/internal carotid artery and internal jugular vein enables selection of a needle trajectory that avoids these structures. In our cohort, intersection of the needle trajectory with the vertebral artery was most commonly seen in those cases requiring a shallow approach in order to avoid carotid sheath structures (Figure 3). Attention to vertebral artery position is thus especially critical in cases for which a shallow trajectory is chosen.

Fluoroscopy-guided techniques rely on bony landmarks for the determination of final needle tip position, and commonly target the posterior border of the neural foramen or anterosuperior margin of the articular process[5,6]. With the foraminal angle approximating the oblique fluoroscopic approach, the vertebral artery covered the needle trajectory in 27 of 70 instances, suggesting the need for exacting final needle tip positioning. In five of our cases performed with CT-fluoroscopy, a negative trajectory angle to the foramen (–10° to –18°) was employed, similar to the posterior-lateral fluoroscopic approach[6], and in all five instances the needle trajectory intersected with the position of the vertebral artery in the foramen. Careful inspection of pre-procedure imaging may be important to assess the location of the vertebral artery prior to needle placement by fluoroscopy. Vertebral artery location may influence final needle tip target position, particularly in the setting of advanced degenerative disease.

Both extraforaminal and transforaminal (intraforaminal) techniques have been described in the literature[2,5,20]. Final needle tip position typically depends upon trajectory options available given the location of the carotid artery and jugular vein. In our experience, either a posterior intraforaminal target site (transforaminal; along the posterior wall of the neural foramen) or extraforaminal target site (adjacent to the posterior-lateral aperture of the foramen) minimizes exposure to potential interaction with the vertebral artery. From this position, corticosteroid distribution (as demonstrated by contrast dispersal) is commonly seen not only surrounding the extraforaminal portion of the nerve root but also extending along the root into the neural foramen. Corticosteroid has been shown to spread by diffusion and axonal transport therefore the effectiveness of nerve root blockade is likely unaffected by the absence of deep intraforaminal delivery of the injection[21].

Cervical radicular pain is most commonly attributed to neural compression from osteophytes arising from facet and/or uncovertebral joints or herniated disc material[22]. We employed a grading scheme for neural foraminal narrowing dividing the foramina into three categories: normal-to-mild narrowing (up to 1/3 reduction in diameter), moderate narrowing (1/3-2/3 reduction in diameter) or severe narrowing (>2/3 reduction in diameter) as judged visually in the axial plane. Other methods for neural foraminal assessment have been described including quantification of foraminal dimensions in the mid-sagittal plane and grading based on a binary system (0-within normal limits or minimally narrowed; 1-moderately to severely narrowed), although no clear consensus for neural foraminal assessment currently exists[23,24]. Herniated disc material may also alter vertebral artery position in a similar fashion as facet/uncovertebral joint-associated osteophytes. Intraprocedure assessment of vertebral artery position can be made when vertebral artery displacement is due to either osteophytic disease or disc herniation.

Choice of corticosteroid preparation is another important factor to consider when performing C-TfEIs. Previous work by Dreyfuss et al. showed no statistically or clinically significant difference in effectiveness between particulate and non-particulate preparations in transforaminal injections for cervical radicular pain[25]. Given the possibility of an embolic phenomenon within radiculomedullary or distal vertebral artery branches, we favor a non-particulate alternative such as dexamethasone for all C-TfEI procedures.

Conclusion

We demonstrate a positive correlation between the severity of degenerative neural foraminal narrowing and vertebral artery position (Chi: $p=0.001$; Kendal's tau-b: $p=0.003$) such that in many patients undergoing C-TfEI the vessel lies in close proximity to the typical target injection site. Awareness of this phenomenon may minimize inadvertent interaction with the vertebral artery during C-TfEI procedures.

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